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Light from the Face of the Deep?

In September 1973 I caught 'flu. My wife said to me, with callous indifference to my misery, "Stop lying there looking sorry for yourself. Why don't you solve the energy crisis?". It seemed a good idea at the time. What she wanted was something which would provide the vast amounts needed, which would be clean and safe, would work in the winter in Scotland and would last for ever. It is a good thing for an engineer to have the design objective clearly specified.

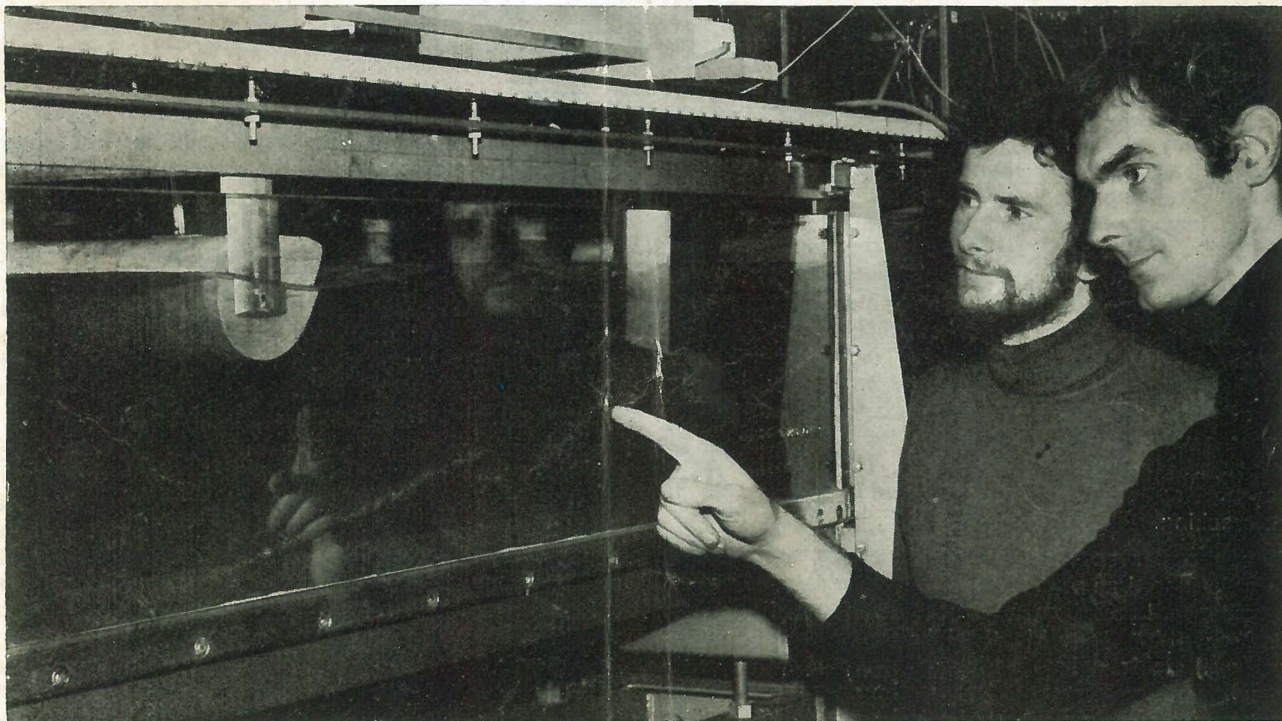
by Stephen Salter

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I thought about several things and then did a few sums about the energy in sea waves, guessing at their sizes. I was amazed at the amount of power that seemed to be available. The obvious extraction mechanism was

something like a lavatory ball-cock bobbing up and down working a pump. I am fortunate to work for a University enlightened enough to provide me with my own workshop facilities. I could get hold of enough balsa wood and transistors to try some tests. It took me very little time to make a dynamometer which could measure the work done by a bobbing ball-cock. Clive Greated in the Department of Fluid Dynamics was kind enough to lend me a tank with a wave-maker in it. The ball-cock floats got out about 15 per cent of the available energy. But I found that if they were tipped so that the hinge was below the surface the extraction was much higher, about 60 per cent. It looked as if the to and fro movement was better than the more obvious up and down.

I then tried a vertical flap. Its movements displaced water behind it to make a new wave with about 25 per cent of the energy, and the extra impedance that this



produced made it harder to move, so that it reflected about 20 per cent back to the wave-maker. I got about 40 per cent out. What I wanted was a flap with no back. I made something like the British Standards kite mark. Its round rump displaced no water as it moved, and could contain a strong mounting. I worked out a shape of pump which could fit inside. Kite got out 70 per cent. Then there was Tadpole which was no better and harder to make.

It was high time to find out how big waves really were. As well as having the best waves in the world Britain is fortunate in having the best wave data. The British Oceanographic Data Service, part of the National Institute of Oceanography, have been measuring them for years. The man who is responsible for this, Laurie Draper, was coming to Edinburgh to talk to oil people and agreed to stop by and look at my models. He brought some of his papers and explained all the details to me. There really was lots of energy there. Doubts about this are noticeably lower among those who have been to sea in small boats and rough weather.

In November there was a conference on "Energy in the Eighties" at the Royal Society in London. I went down the day before and called on the University's Patent Agent and looked at abstracts. There were hundreds of them. Some did tides as well as waves. There were many bobbles-up-and-down but none like my shapes. I wrote out a patent that afternoon while Princess Anne was getting married.

The next day distinguished speakers addressed a distinguished audience. Peter Walker said that the best thing to do was to get the oil out as fast as possible.

There was supreme confidence and doubt, talk of tar sands and geothermal energy, hydro-electricity and tides, nuclear safety and pollution. There was nothing about waves. London was clearing up after the royal wedding, the miners were deciding to work to rule, the Arabs were feeling their strength.

a large box

In the lobby of Carlton House was a large box full of copies of a paper by a man called Amory Lovins, who worked with a group called "Friends of the Earth". I took a copy and read it that night. It was called *World Energy—Facts, Issues and Opinions*, (£1 inc. postage from 9 Poland Street, London W.1.). It influenced me profoundly. In meticulous detail, with hundreds of references, Lovins described what was available, how long it might last, and what might be the side effects. "Side" is not really the way to describe the effects of the collision of methane tankers. Energy research was no longer for me a bit of a joke to fill in between projects. It was time, if the light water pressure-vessel designers will forgive the expression, to get cracking.

About ten per cent of the population of this country suffer, at one time or another, from some form of mental disturbance. In a fair number of them the manifestations involve writing to cabinet ministers. In normal times the mail is evenly distributed among the various branches of government. But at the end of 1973 the trousers-for-dogs and bring-back-the-cat letters faded

away and with one mind all the writers switched to helpful proposals for solving the energy crisis: tread-mills for fat business men, sewage-driven cars . . . I chipped in with a short letter to Peter Walker who was then responsible for energy. In due course I received a polite acknowledgement. But my letter took some time to filter through channels. Eventually it reached the Energy Technology Division of the Department of Energy then part of the old D.T.I. They had themselves produced a wave power scheme, costed it and found that it was not totally absurd. It seemed a good idea that we should get together. However, the fact that my note had come from the School of Artificial Intelligence and some quirk of my literary style suggested that the whole business was a cruel hoax against Peter Walker when he was battling with Joe Gormley and the Arabs.

Their initial approach was very tentative. But they were soon in Edinburgh looking at models and giving good advice. The subsequent course of the project has been greatly assisted by their help. People's reactions to the whole idea have been varied. At the beginning there were some whose instant response was to dismiss it as ridiculous. They may yet be proved right, but the reasons will be complicated and interesting. However, there were a number of senior members of the University who listened seriously, gave up time, wrote letters and encouraged me to carry on.

By this stage I was getting a lot of help from Peter Buneman (now, alas, in America) and Denis Mollison, a mathematician from Heriot-Watt University. We had long discussions about how to design the optimal shape.

Waves drive each other with very high efficiency. They go as many miles as they have feet in their wave length before they lose half their power. If we could make them think that they were driving another wave then that would be one way at least to get a very good shape.

in deep water

In a travelling wave in deep water each particle moves in a nearly circular orbit. At the surface the diameters of these circles are the same as the wave height, and the diameter falls off exponentially as you go down.

We knew that the round back was right. If we could make the front have a shape which displaced water in proportion to the sizes of the circles at each depth, then the wave would not notice anything different. Peter and Denis and a computer tried to grow the shape down from the surface. I had a feeling that we should grow it up from the bottom but they were quite sure.

I went away and tried with a slide rule. By Saturday morning I had a combination of a circle and a tangent which fitted fairly closely the displacements we were after. I made it out of balsa wood and went out for lunch. But on the way I saw Peter's car parked, and realised he must be in the computer room. I went back to fetch my model, still wet with varnish, and took it in to him. When he saw me he said "It does grow from the bottom. Come and see". He had used a one-to-one scale on his print-out. I put my shape on top of it. It fitted closely. We call this shape "pregnant duck"—

descriptively, if not biologically, satisfactory. Duck can get 90 per cent at its best and is admirably compact. We can if need be afford to throw away efficiency to buy reliability or cheaper construction.

Peter did a lot more computing for me on wave calculations. During the Christmas holiday we worked at night in between the voltage reductions. The 4130 computer at Forrest Hill was very touchy about the mains level. At critical moments there would be a loud hooting noise from the mains-low alarm and we would have to shut down. I bought a battery powered calculator. We squeezed some interesting results from Draper's figures. We found that the mean annual power density in the North Atlantic was nearly 80 kw per metre of frontage. This holds up all the way in to the Hebrides. We found that most of the energy was from waves with periods between 9 and 12 seconds. We found that at times it must be an awful place. The power density can exceed one megawatt per metre.

testing models

I was still testing models. Making accurate measurements proved to be extremely difficult. I could measure the amount of energy getting past the model, getting reflected, and going into the dynamometer. The general idea is that this should add up to the amount coming in. But I found that the size of wave in the tank was very unstable. Although everything seemed to be held steady the waves could vary by 30 per cent. It was nearly as bad as being at sea. I would be dashing up and down reading meters and oscilloscopes over and over again and finding they were never twice the same. It was most embarrassing when the efficiency came out as more than 100 per cent. It turned out that the trouble was in the wave-maker.

There are a number of sorts of wave-maker used in test tanks. This one was a vertical flap hinged at the

bottom of the tank driven by a crank on an electric motor. If any waves were reflected from the model they would come back to the wave-maker which would behave like a cliff and reflect them once more. But this would be further complicated because the flap would be in motion. This produces a Doppler shift. It is difficult to think of it that way if the velocity is changing at the same frequency as the wave but I am sure that this is so. Anyway the new lot of waves get added to the residues of the old and beat with them. I had to make a new sort of wave-maker which could absorb waves like the model as well as making them. The Doppler effect will occur in all wave tanks where appreciable amounts of energy can return to meet their maker. I hope this new design will allow people to do experiments in much smaller tanks. This development was helped and encouraged by Professor Halliwell and some very civil engineers from Heriot-Watt.

tremendous problems

Wave power became respectable after the Rothschild Report in July 1974. Whether or not it will ever light an honest bulb for us is hard to say. There are tremendous problems still to be solved. But Britain does not have all that much uranium and the countries that do have it may not hand it over just for old times' sake.

The Department of Industry have given enough money to buy all the balsa wood and transistors that I can use over the next three years, and to pay David Jeffrey who is now working with me. I have another job vacant.

The successful candidate will have to work extremely hard in difficult conditions. He should be expert in Physics, Mathematics, Electronics, Naval Architecture, Stress Analysis, Biology (because of the barnacles), Computer Programming, Meteorology, Economics, Politics and Public Relations.

Honorary Graduands for November Ceremony

The University of Edinburgh will confer the following Honorary Degrees at a Graduation Ceremony to be held on Saturday, November 23:

● **Professor David Maxwell Walker, Q.C., M.A., LL.B., (Glasgow), LL.B., LL.D., (London), Ph.D., LL.D. (Edinburgh),** Regius Professor of Law, Department of Private Law, University of Glasgow: For the Honorary Degree of Doctor of Laws.

● **Dr. Ian Douglas-Wilson, M.D., F.R.C.P.E.,** Editor of *Lancet*: For the Honorary Degree of Doctor honoris causa.

● **Mr David Leslie Medd, O.B.E., A.R.I.B.A., A.A. Dip(Hon.),** Principal Architect Department of Education and Science: For the Honorary Degree of Doctor of Science in the Faculty of Social Sciences.

● **Dr. William MacGregor Henderson, D.Sc., F.R.C.V.S., F.I.Biol.,** Secretary to the Agricultural Research Council: For the Honorary Degree of Doctor of Veterinary Medicine and Surgery.

For the information of *Bulletin* readers short biographical

notes are given of the proposed recipients of Honorary Degrees.

● **Professor D. M. Walker,** graduated from the University of Glasgow in 1946, after service with the Indian Army in India, Africa and Italy, and subsequently studied at the Universities of Edinburgh and London. He joined the Scottish Bar in 1948, practising until he occupied the Chair of Jurisprudence in the University of Glasgow, a position he held from 1954 until 1958 when he became a QC (Scotland), and Regius Professor of Law at Glasgow. He is also a member of the English Bar.

Professor Walker is best known as a legal writer. His massive publications include—*Faculty Digest of Decisions 1940-1950* (1953); *Law of Damages in Scotland* (1955); *The Scottish Legal System, 3rd Edition* (1969) with the 4th Edition in preparation; *Scottish Courts and Tribunals, 2nd Edition* (1972); *Principles of Scottish Private Law, 2 Volumes* (1970) with 2nd Edition in preparation; *Law of Prescription and Limitation in Scotland* (1973) with 2nd Edition in